CIRCULAR No. 337 DECEMBER 1934
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

FIELD PRACTICES AFFECTING THE CONTROL OF COTTON ROOT KNOT IN ARIZONA

By C. J. King, *agronomist*, and Claude Hope, *junior horticulturist, Division of Cotton and Other Fiber Crops and Diseases, Bureau of Plant Industry*

CONTENTS

INTRODUCTION

Root knot is one of the most important diseases of cotton and occurs to some extent in every State where cotton is grown. The disease attacks not only cotton but also several hundred other kinds of plants. It is most destructive in soils of sandy character and is often responsible for heavy losses in many garden crops and orchards. It has been observed for many years in the southern portions of Arizona and California, affecting crops such as melons, tomatoes, peas, beans, figs, grapes, and deciduous fruit trees.

Recently the disease has become a problem in the production of cotton in parts of the Salt River Valley, Ariz. So far, its occurrence has been limited largely to the lighter soil types and the principal damage has occurred on the Pima Egyptian type of cotton, which appears to be somewhat more susceptible than upland varieties.

The effects of root knot on cotton were first observed at the United States Field Station, Sacaton, Ariz., in 1920, though definite identification was not made until 1921. Except in small areas the disease did not become serious until 1926, when the infestation became so severe in some plots that it became difficult to obtain good stands of Egyptian cotton, and frequently large areas of mature plants died in late summer and early fall. After the disease became severe on mature plants, the areas of dead plants were mapped, and those which were most affected were planted to nonsusceptible crops.

No control experiments were attempted before 1931. Prior to that time, however, certain cultural practices aimed at the control of other cotton diseases or incidental to other experiments had shown effects on the severity of the disease. Indications of control by rotation with alfalfa and control, or, if possible, eradication, by clean fallowing, together with the effect of early irrigation suggest that more ready and effective control may be possible in the hot, dry, irrigated areas than in the humid regions where most of the root-knot studies have been conducted.

This circular deals with the effects of fallowing, crop rotations, and irrigation on the incidence and severity of the disease at Sacaton, Ariz.

SYMPTOMS, CAUSE, AND SPREAD OF THE DISEASE

Cotton plants severely diseased with root knot are usually stunted, and the leaves and stems are a pale yellowish green. If the attack is mild, the symptoms may not be noted, and the farmer may remain unaware that any trouble is present and attribute poor yields to low fertility.

The nematodes, *Heterodera marioni* (Cornu) Goodey, which cause the disease, may attack the cotton plants in the seedling stage, and

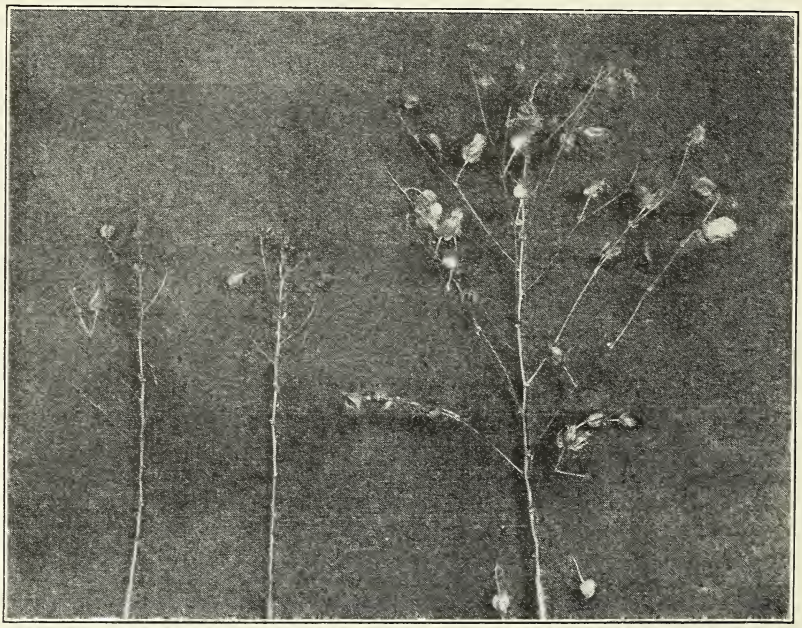

FIGURE 1.—A comparison of a normal (right) with two root-knot-affected Pima cotton plants (left). Note the absence of low fruiting branches on the diseased plants, which gives them a whiplike appearance. The leaves were removed for photographing. Photographed August 16, 1933.

poor stands frequently result where they are abundant and active. In Pima cotton, affected plants seldom develop vegetative or fruiting branches on the lower 15 or 20 nodes, and the plants have a whiplike appearance (fig. 1). The lower leaves gradually drop off so that late in the season only a tuft of yellowish-green leaves may remain on the upper branches. In some years large areas of plants that had previously shown only mild symptoms may die late in the season.

The roots of cotton plants attacked by nematodes show a development of galls varying in size from that of a pinhead to half an inch in diameter (fig. 2). These galls result from a local stimulation caused by the nematodes and interfere with the nutrition and water supply of the plant. When a gall is cut open the female nematodes can usually be seen as pearly white, rounded or pear-shaped objects, about one twenty-fifth of an inch long. The females lay from 50 to 500 eggs

which hatch into young worms or larvae, usually within a few days. The larvae migrate farther into the tissues or escape into the soil and attach themselves to other roots which they penetrate and on which they cause further gall formation. The young male matures in 3 to 4 weeks and promptly dies after fertilizing the female. The nematodes live over from one season to another in the soil or in the roots of plants.

The root-knot nematodes are easily spread and are doubtless carried by several agencies. One of the commonest means of dispersal is the transfer of rooted plants from infested to noninfested areas. It is generally believed that they are transported also by irrigation

FIGURE 2.—Nematode galls on the roots of a Pima cotton plant. Affected roots decay more rapidly in the fall and winter than normal roots, being more open to the attack of secondary organisms.

and drainage water and by farm implements and vehicles. Hagan [1] from recent studies in Hawaii doubts that *Heterodera marioni* is spread by such mechanical means as transport on shoes, the feet of horses, and winds, when only the first inch or two of soil is carried away. The writers agree with this view, in general, especially for hot climatic conditions, although at Sacaton cases have been observed which indicated spread by irrigation water and farm implements.

An example of apparent spread by tillage implements was noted at the Sacaton seed farm in 1930–31 (fig. 3). A deciduous orchard at the west side of the farm was found to be infested with root-knot nematodes in 1922. A period of about 8 years elapsed before spread to any other portion of the farm was observed. In 1930 the disease appeared in Pima cotton planted in a series of plots on the east side of the farm about 75 rods from the infested orchard. The root-knot infestation when mapped in the fall of 1931 extended from the south edge over parts of six "borders." [2] However, during the winter of 1929–30, the direction of the borders had been changed slightly to obtain a better grade. With the borders plotted as they lay in 1929, the disease covered a greater part of the first and second borders on

[1] HAGAN, H. R. HAWAIIAN PINEAPPLE FIELD SOIL TEMPERATURES IN RELATION TO THE NEMATODE HETERODERA RADICICOLA (GREEF) MULLER. Soil Sci. 36: 83–95. 1933.

[2] "Border" is an irrigation term which refers to the strips of land, usually 33 to 66 feet wide between the ridges, which are constructed to control the flow of the water.

the south edge and in one place extended across the third and part of the fourth border. Some of the tillage implements used in this field were also previously used in the infested orchard, and the disease appeared where the disk, harrows, cultivators, and other implements coming from infested land usually entered.

SUSCEPTIBILITY OF PIMA AND UPLAND COTTON

Upland-cotton plants are readily attacked by the root-knot nematodes, but they undergo less injury than Pima plants grown under similar conditions. The relative resistance of upland cotton in the irrigated region has been judged largely by the behavior of Acala, which is the variety most generally grown. However, all upland varieties grown in infested areas at the United States Field Station at Sacaton appeared to be equally resistant. These included Hartsville, Lone Star, Mebane Triumph, Delfos, Durango, King, and Hopi.

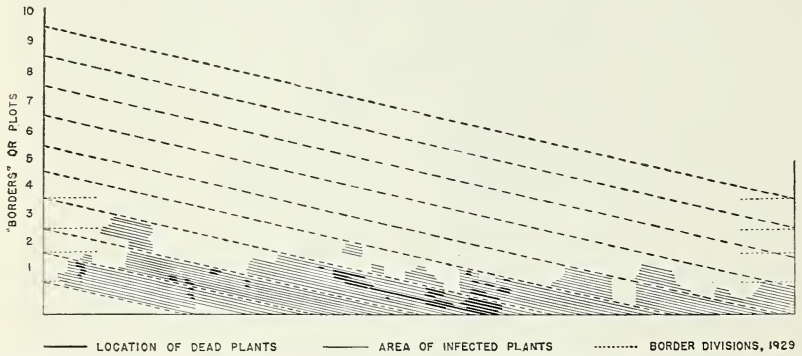

FIGURE 3.—Diagram of a root-knot infestation in a field of Pima cotton on the seed farm to which nematodes apparently were introduced by transfer of cultivating implements from infested areas. The disease is confined to a strip at the south edge, which would represent about four "borders" if laid out parallel to the boundaries as they had been prior to 1930.

In 1932 the Pima and Acala varieties were planted alternately in 3- and 4-row blocks on a series of quarter-acre plots that were known to be slightly infested with root-knot nematodes. A large number of plants died in the seedling stage, so that the stand was greatly reduced, but after thinning time the plants made considerable growth and showed but few indications of being diseased. The Pima plants, however, were not fruitful, and yields were much lower than those from the Acala.

In January 1933, after picking was completed, a number of consecutive plants in adjacent rows of Pima and Acala were spaded up on three of the plots and the roots were examined. The roots of all of the Pima plants were covered with nematode galls and many of them were badly decayed. Only 25 percent of the roots of the Acala plants were affected with galls and there was little decay in the tissues (fig. 4).

A classification of the nematode injury, as indicated by root condition, is shown in table 1.

TABLE 1.—*Classification of root-knot nematode injury to roots of Pima and Acala cotton in adjacent rows, plots C1–12 to C1–14 in crop of 1932*

Plot no.	Variety	Roots from consecutive plants	Noninfested	Infested	Many galls and rotted roots	Few galls, no dead roots
		Number	*Number*	*Number*	*Number*	*Number*
C1–12	Pima	22	0	22	9	13
	Acala	21	12	9	0	9
C1–13	Pima	23	0	23	17	6
	Acala	22	20	2	0	2
C1–14	Pima	26	0	26	16	10
	Acala	30	23	7	0	7
Total	Pima	71	0	71	42	29
	Acala	73	55	18	0	18

The history of cotton behavior on some of the station plots shows that yields of Pima are reduced to a greater extent than those of

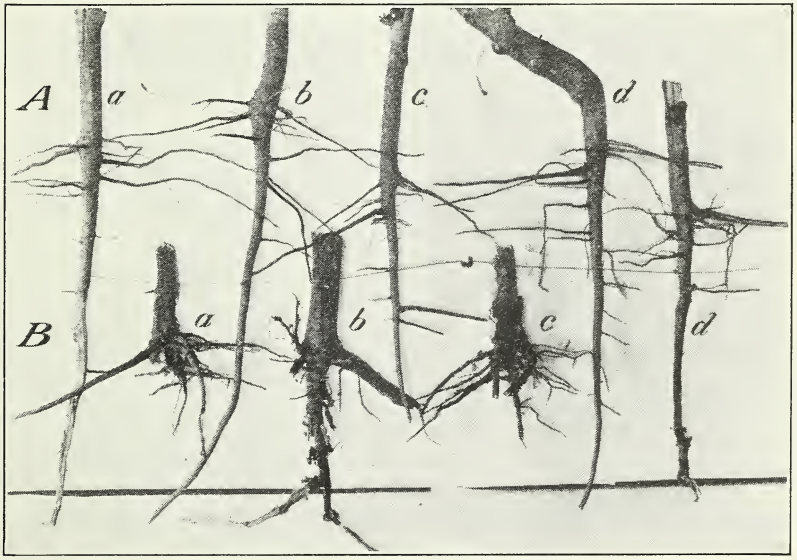

FIGURE 4.—Comparison of root-knot nematode injuries on four consecutive pairs of Acala (*A–a, b, c,* and *d*) and Pima (*B–a, b, c,* and *d*) cotton roots from adjacent rows in plot C1–13 in 1932. The upland roots had a few galls but no rotted tissues. These are representative of 20 consecutive pairs (per plot) spaded up on each of three plots.

upland in infested areas continuously cropped to cotton. This was noted in a series of plots included in a manurial experiment for the control of root rot, another disease which affected the same area. Alternate plots received applications of manure in deep trenches each winter for several years, and the others were used as controls. The area was planted to Pima cotton from 1919 to 1930. About 1925 it was noted that some of the plants were affected by root knot. As the infestation became more general throughout the area, it became increasingly difficult to distinguish between damage caused by the root-rot fungus and that caused by the root-knot nematodes. Since it was known that upland plants seldom died from root knot under Arizona conditions, the Acala variety was substituted for Pima in

this area in 1931. The Acala plants showed little injury from root knot, and the yields were much higher than had been the yields of Pima on the same plots during the previous 6 years (table 2). The Acala yields in 1932 were much less than in 1931, but a greater number of plants were killed by the root-rot fungus.

TABLE 2.—*Acre yield of Pima seed cotton, 1925–30 and Acala seed cotton, 1931–32, from manured and unmanured plots infested with root-knot nematodes and root rot at the United States Field Station, Sacaton, Ariz.*

Plot no.	Treatment	Pima						Acala	
		1925	1926	1927	1928	1929	1930	1931	1932
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
C2–16	Control	766	1,057	878	787	769	834	1,916	1,676
C2–17	Manured 1923–32	1,043	1,239	1,522	1,318	794	852	2,406	2,177
C2–18	Control	899	1,042	902	1,011	568	398	2,168	1,389
C2–19	Manured 1921–32	1,327	1,308	1,415	[1] 1,387	710	797	2,281	2,142
C2–20	Control	1,109	1,048	939	1,036	804	448	2,045	1,770
C2–21	Manured 1923–32	911	953	992	1,478	[2]	1,178	2,219	1,964
C2–22	Control	812	724	819	1,033	[3]	829	2,035	1,323
C2–23	Manured 1923–32	1,281	1,024	962	995	[2]	1,058	2,182	1,534
C2–24	Control	587	396	746	688	[3]	927	1,993	909

[1] No manure applied to plot C2–19 in 1928. [2] Plot in alfalfa. [3] Plot fallowed.

The above observations do not justify a substitution of upland for Pima cotton on infested areas. Infestations remain active, as long as cotton is grown, and are a menace to other disease-free areas. It is preferable to eradicate the root-knot nematodes.

ROTATION OF COTTON WITH ALFALFA

Alfalfa is a host plant for the root-knot nematode, but the effects on this crop are never severe. In Arizona and southern California injuries are so slight that they are practically negligible. Results obtained at the United States Field Station at Sacaton indicate that satisfactory yields of cotton may be maintained on root-knot nematode-infested areas by rotating every 2 or 3 years with alfalfa. This system seems to be almost as beneficial from the standpoint of yields as clean fallowing, although the nematodes are not eradicated by this means.

The influence of alfalfa rotations in increasing the yields of Pima and upland cotton on root-knot nematode-infested areas is clearly indicated in the data from 18 quarter-acre plots that showed a limited infestation in 1920, and a more general infestation in 1927. The yields of the two types of cotton on these plots during the years 1919 to 1932 and the years in which alfalfa was grown in rotation are given in table 3.

TABLE 3.—*Acre yields of Pima and upland seed cotton when rotated with alfalfa on block C1, an area infested for at least 13 years with root-knot nematodes, United States Field Station, Sacaton, Ariz., 1919–32*

Plot no.	1919, Pima	1920, Pima	1921, Pima	1922		1923		1924		1925		1926	
				Pima	Upland [1]	Pima	Upland	Pima	Upland	Pima	Upland	Pima	Upland
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
C1–1	(3)			(4)	(4)	(3)	(3)	(3)	(3)				
C1–2	(3)					(3)	(3)	(3)	(3)	1,938	3,127	1,905	2,542
C1–3	(3)	1,961	1,488			(3)	(3)	(3)	(3)	1,800	2,728	1,836	2,513
C1–4	(3)	2,292	1,605			(3)	(3)	(3)	(3)	1,918	2,663	1,860	2,506
C1–5	(3)	1,624	1,303	1,125		(3)	(3)	(3)	(3)	1,962	2,619	1,769	2,345
C1–6	(3)	1,627			1,147	(3)	(3)	(3)	(3)	2,168	2,519	1,854	2,477
C1–7	1,666	1,753		907		(3)	(3)	(3)	(3)	2,049	2,408	1,676	2,482
C1–8	1,953	1,458			1,441	(3)	(3)	(3)	(3)	1,929	2,358	1,885	2,432
C1–9	1,896	1,543	1,493	1,160		(3)	(3)			1,394	2,362	1,438	2,107
C1–10	1,984	1,590	1,574	859		1,571		1,206				1,785	
C1–11	1,790	1,536	1,332	897			1,995	1,564	1,707	1,212		1,347	
C1–12	2,250	1,462	1,334	808		1,431		1,461	1,695	1,271		1,283	
C1–13	2,017	1,703	1,324	1,042			2,339	1,368	1,739	1,255		1,388	
C1–14	1,781	1,750	1,376	1,044		1,461		1,280	1,500	1,169		1,372	
C1–15	1,570			889			2,209	1,358	1,437	1,135		1,377	
C1–16				978		980	2,138	1,289	1,307	1,310			
C1–17				1,465		706	1,910	1,334	1,317	1,365			
C1–18				1,226		772	1,640	1,093	1,426	1,178			

Plot no.	1927		1928, upland [1]	1929		1930		1931		1932	
	Pima	Upland		Pima	Upland [1]	Pima	Upland [1]	Pima [2]	Upland	Pima [2]	Upland
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
C1–1				777	1,515	622		(3)	(3)	(3)	(3)
C1–2	1,194	2,308		1,491	2,162	882		(3)	(3)	(3)	(3)
C1–3	1,347	2,146	1,868		2,288		2,080	(3)	(3)	(3)	(3)
C1–4	1,380	2,367	2,056		1,936		2,088	(3)	(3)	(3)	(3)
C1–5	1,425	2,156	2,083		1,960		2,128	(3)	(3)	(3)	(3)
C1–6	1,196	2,075	1,954		1,862		1,893	(3)	(3)	(3)	(3)
C1–7	1,692	2,360	2,094		1,772		1,990	(3)	(3)	(3)	(3)
C1–8	1,415	2,417	2,150		2,034		2,074	878	2,139		
C1–9	1,509	2,122	1,932		1,626		[2] 1,080	1,017	1,761		
C1–10	1,396		1,797	(3)	(3)	(3)	(3)	1,324	2,291		
C1–11	1,447		2,118	(3)	(3)	(3)	(3)	1,300	2,599	1,065	2,704
C1–12	1,511		1,930	(3)	(3)	(3)	(3)	1,112	2,374	920	2,637
C1–13	1,494		2,225	(3)	(3)	(3)	(3)	1,153	2,459	837	2,823
C1–14	1,465		1,862	(3)	(3)	(3)	(3)	1,204	2,631	889	2,664
C1–15	1,542		1,990	(3)	(3)	(3)	(3)		2,554		2,973
C1–16			1,958	(3)	(3)	(3)	(3)		2,422		2,403
C1–17			1,734	(3)	(3)	(3)	(3)		2,487		2,259
C1–18		1,651	1,714	(3)	(3)	(3)	(3)		2,247		2,043

[1] Upland varieties other than Acala were included.
[2] Poor stand.
[3] Plots in alfalfa.
[4] Plots in guar, a leguminous forage crop.

It will be noted that yields are given in some years for Pima and Acala on the same plot. In these cases 3 or 4 rows of each were grown in adjacent strips.

In all cases where no cotton yields or other crops are given in the table, the plots were planted to cotton for studies on breeding, genetics, or other purposes, and the yields were not recorded or were of no agronomic value.

During the period 1920–23 the infestation was most extensive on plots C1–1 to C1–9, and a gradual decline in the yields of Pima cotton is noted. After 2 years in alfalfa, the yields of both Pima and upland cottons showed an abrupt increase in 1925, which was not shown in plots 10 to 18 that had not been in alfalfa. After 1926, Pima was not planted except on plots C1–1 and C1–2 of the east half of the block,

but the yields on these were unsatisfactory because of the root-knot disease. Upland cotton, however, was grown for 6 consecutive years in the other eight plots without a serious decline in yield. After alfalfa had been grown during 1929 and 1930 on plots C1–11 to C1–18, there were indications of increased yields in the upland planted in 1931 and 1932, but the Pima fared badly from several unfavorable factors in the seedling stage during these years, and the yields did not reflect any advantage from the alfalfa rotation.

In other infested areas at the station, corn, sorghums, and small grains were used at various times in rotation with cotton. The increased yields of Pima cotton following these and other less susceptible

FIGURE 5.—Effect of crop rotation on the control of cotton root knot. The large Pima plants in the foreground were on an area on which no cotton had been planted for 2 years. Sesbania, onions, and vetch were grown in 1931–32, followed by Pima cotton in 1933. The stunted and diseased cotton plants beyond the white stakes were in an area that had been continuously in cotton for 9 years.

crops indicate that rotations which include these crops are also beneficial in controlling root knot (fig. 5).

CLEAN FALLOWING

Under the dry climatic conditions which exist in southern Arizona, a system of clean fallowing without irrigation appears to offer a very effective means of controlling root-knot nematodes and possibly of completely eradicating them when prolonged for 3 or 4 years. Recent investigations by Godfrey and Hoshino [3] show that nematode eggs and larvae are readily killed when exposed to dryness, heat, or sunlight. When subjected to the combined effects of these conditions, eggs in root-gall tissues of cowpea roots were killed in 8 hours and in pineapple roots in about 16 hours.

Experiments at Sacaton indicate that these factors are also effective under field conditions. Three plots infested with root-knot

[3] GODFREY, C. H., and HOSHINO, H. M. STUDIES ON CERTAIN ENVIRONMENTAL RELATIONS OF THE ROOT-KNOT NEMATODE, HETERODERA RADICICOLA. Phytopathology 23: 41–62, illus. 1933.

nematodes and with cotton root-rot fungus *Phymatotrichum omnivorum* (Shear) Dug., were fallowed during the years 1926 and 1927, without irrigation water being applied. During this period the soil was frequently stirred, being plowed 3 times and disk cultivated 8 or 10 times. The plots were replanted to Pima cotton in 1928 and again in 1929. There were no symptoms of nematode injury on the plants in 1928, although in 1929 plants on the outside rows adjacent to infested plots showed symptoms of the disease. The extent of the root-rot infestation in 1928 was about the same as in 1925, previous to fallowing, but the yields of cotton were much higher, indicating beneficial effects of the treatment in controlling the nematodes. The yields of Pima cotton on the three plots in 1925 and in 1928 are given in table 4.

TABLE 4.—*Acre yields of Pima seed cotton before and after 2 years of clean fallow on plots severely infested with root-knot nematodes*

Plot no.	1925	1926	1927	1928
	Pounds			*Pounds*
C3–1	696	[1]	[1]	1,593
C3–2	1,367	[1]	[1]	2,319
C3–3	1,735	[1]	[1]	2,235

[1] Clean fallow.

In the manurial experiment, discussed on page 6, aimed at the control of the root-rot disease, the number of Pima plants killed by root-knot nematodes on four of the plots in 1928 was so great that it was thought necessary to give the area a rest from cotton. The two manured plots C2–21 and C2–23 were planted to alfalfa early in the spring of 1929, and the control plots C2–22 and C2–24 were kept fallow with clean cultivation. In the spring of 1930 the entire area was again planted to Pima cotton. Late in the fall, the areas of plants that died from root knot were mapped as in 1928. The maps for the two seasons are shown in figure 6, *A* and *B*. While there are indications that the 1 year of fallow or alfalfa was effective in reducing the number of plants killed by root knot, it is apparent that a longer period is required to obtain a satisfactory control or to approach eradication.

In another area on which the cotton crop of 1927 was severely affected by both diseases, a fallow experiment was instituted early in 1928. Plots C3–9 and C3–10 comprising an area of about one-half acre were covered with mulch paper, except for a small control area, and were kept free from all plant growth during 1928 and 1929. One-half of the adjacent plot C3–11 was maintained as a clean fallow by frequent cultivations with a disk harrow during the same years, and plot C3–8 was kept in cotton continuously. In 1930 Pima cotton was planted on all four plots. The plants on the paper-mulch fallow and those on clean-cultivation fallow plots showed no above-ground indications of nematode injury during the season, but those on the continuously cropped plot suffered severely. The root-rot fungus killed many plants on the plots late in the season, but satisfactory yields were obtained in spite of this disadvantage. The comparative yields on the four plots are given in table 5.

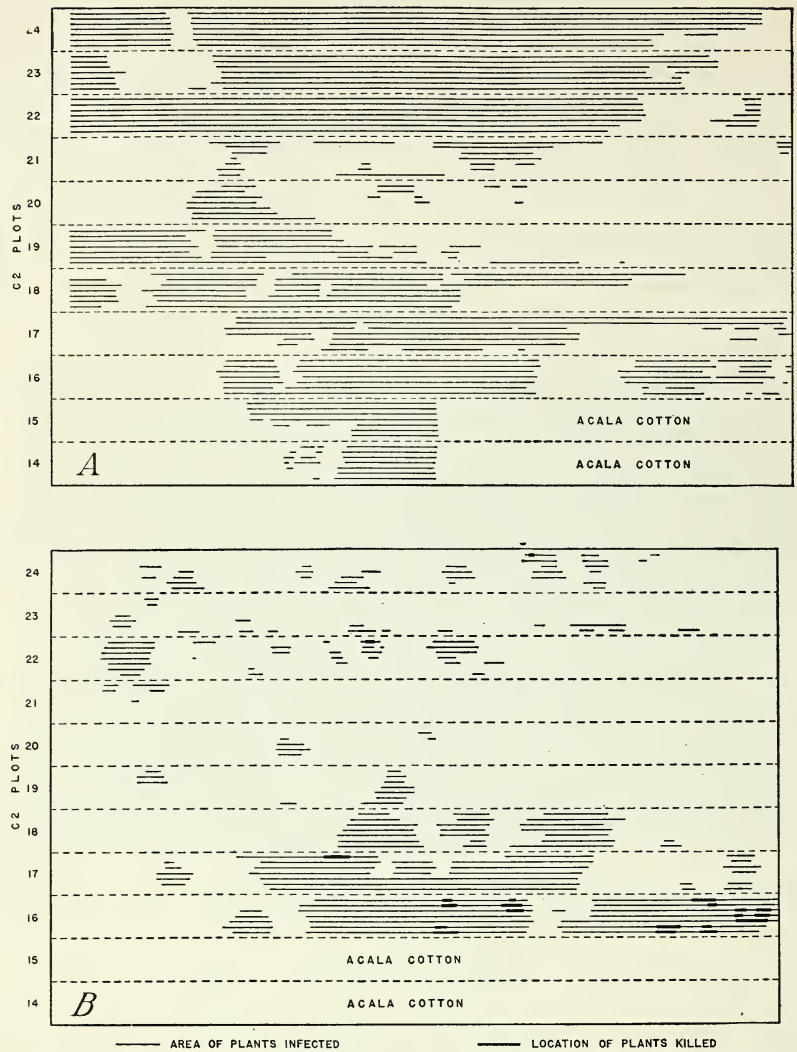

FIGURE 6.—Influence of fallowing and of alfalfa rotation in reducing the extent of nematode damage to Pima cotton: *A*, Areas of Pima cotton plants killed or severely damaged by nematodes in plots C2-14 to C2-24 at the United States Field Station, Sacaton, Ariz., in 1928; *B*, areas of nematode-affected plants on plots C2-16 to C2-24 in 1930. Plots C2-21 and C2-23 were in alfalfa, and plots C2-22 and C2-24 were fallowed in 1929, which accounts for the reduced nematode infestation in these plots in 1930 (table 2).

TABLE 5.—*Comparative yields of Pima seed cotton in three root-knot nematode-infested plots that had been clean fallowed for 2 years and an adjacent infested plot continuously in cotton for 6 years, at the United States Field Station, Sacaton, Ariz., 1930*

Plot	Treatment	Yield of seed cotton per acre [1]
		Pounds
C3-9B	Fallowed 1928-29, covered with mulch paper	1,233
C3-10B	——do	1,438
C3-11B	Fallowed 1928-29, kept clean by frequent cultivations	911
C3-8B	Continuous cotton 1925-30	307

[1] Computed on basis of areas free from root rot.

It is significant that the outside row of the continuous cotton plot adjacent to the fallowed area yielded at a rate about three times that of the other six rows. Apparently the plants derived some benefit

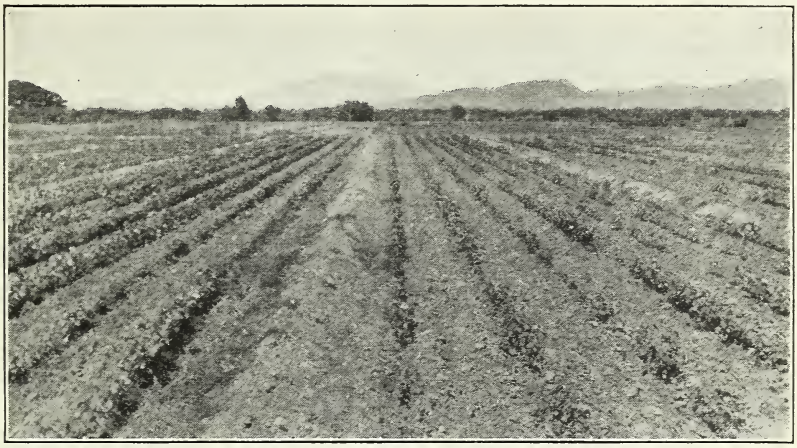

FIGURE 7.—Evidence of paper-mulch fallow effects in controlling root-knot nematodes on cotton seedlings. Left, Pima and Acala in alternate rows the second year after 2 years of paper-mulch fallow. Right, Pima and Sakel in alternate rows continuous cotton, seedling stand dying June 9, 1931.

from having part of their root system in an area comparatively free from root-knot nematodes. In the crop of the following year it was apparent that the disease spread from this row into the adjacent row of the area that had been fallowed. Except for this infection from the outside, there was little indication of the disease in these plots during 1931 (fig. 7), but in 1932–33 it was more extensive.

EARLY IRRIGATIONS

In mapping the areas of Pima plants that had been killed by root knot on a block of 18 plots in 1927, it was noted that there was a marked difference in the number of plants killed in plots C1–2, 4, 6, and 8 as compared to alternate plots C1–3, 5, 7, and 9. The dead plants along the rows were almost continuous on the even-numbered plots, while in the odd-numbered plots many live plants were interspersed among the dead ones (fig. 8). The only explanation that could be found for this difference was that the disease had been affected by the irrigation treatment. The odd-numbered plots received two irrigations in May and a third one on June 21, while the even-numbered plots were not irrigated until June 21. It was not noted that there was any difference in the early activity of the nematodes in these differently treated plots. Apparently the stands were about equal throughout the area when the dead plants were mapped in the fall.

Flooding has been advocated as a means of root-knot control, but since the disease is most prevalent in sandy areas, practical difficulties may be encountered in maintaining the soil in a saturated condition. The apparent effect of early irrigations suggests that flooding during the winter or spring might be more effective than flooding or irrigating frequently during the summer.

SUMMARY

The root-knot disease caused by the nematode *Heterodera marioni* has become a problem in the production of cotton in certain districts in Arizona.

Root knot is an insidious disease, and since the infected plants may show no conspicuous symptoms, large areas may become unproductive for cotton before the farmer is aware of the real trouble.

Pima plants severely affected with root knot are likely to be stunted, and, since branching at the lower nodes is suppressed,

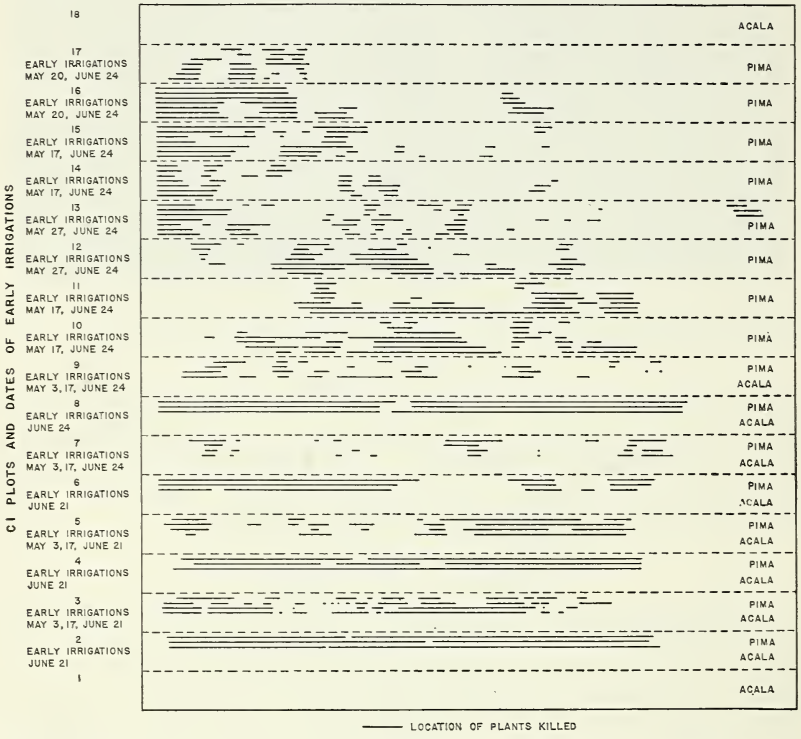

FIGURE 8.—Influence of early irrigations on the extent of area of Pima cotton plants severely damaged by root-knot nematodes at the United States Field Station, Sacaton, Ariz., in November 1927. Plots C1–3, 5, 7, and 9 received two irrigations in May, and the disease was less severe on these plots in the fall than on alternate plots C1–2, 4, 6, and 8 which received the first irrigation June 21.

they have a whiplike appearance. The leaves of diseased Pima or upland plants are a pale yellowish green, and the lower leaves gradually drop off as the plants approach maturity.

The transfer of cultivating implements from infested areas apparently was responsible for the introduction of root-knot nematodes to a field of Pima cotton, free from the disease.

The root-knot nematodes attack both upland and Pima cotton, but the injuries to Pima are more severe and the yields decline more rapidly when infested areas are planted to cotton continuously.

In severely affected areas seedling stands are reduced and in some seasons many mature plants succumb late in the season.

An examination of the roots of several consecutive plants of Pima and Acala cottons without aboveground symptoms located in adjacent rows in four different infested plots showed that 100 percent of the Pima plants were affected with nematode galls, and only 25 percent of the Acala plants were so affected.

Rotation with alfalfa was effective in maintaining satisfactory yields of Pima cotton in severely infested areas, but there were no indications that the nematodes could be eradicated by this means.

Two years of clean fallow, with either a mulch-paper cover or clean cultivation, proved effective in controlling root knot, and indicated that a more prolonged period of dry fallow might eradicate the nematodes.

There was evidence, from one experiment, that early irrigation reduced the severity of the root-knot disease in Pima cotton. Fewer plants died in the fall on plots thus treated as compared to adjacent plots which received no early irrigations.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	HENRY A. WALLACE.
Under Secretary	REXFORD G. TUGWELL.
Assistant Secretary	M. L. WILSON.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Director of Finance	W. A. JUMP.
Solicitor	SETH THOMAS.
Agricultural Adjustment Administration	CHESTER C. DAVIS, *Administrator.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Biological Survey	J. N. DARLING, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology and Plant Quarantine	LEE A. STRONG, *Chief.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Chief.*
Forest Service	FERDINAND A. SILCOX, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Bureau of Plant Industry	FREDERICK D. RICHEY, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Weather Bureau	WILLIS R. GREGG, *Chief.*

This bulletin is a contribution from

Bureau of Plant Industry	FREDERICK D. RICHEY, *Chief.*
Division of Cotton and Other Fiber Crops and Diseases.	M. A. MCCALL, *Principal Agronomist, in Charge.*

14

U. S. GOVERNMENT PRINTING OFFICE: 1934

For sale by the Superintendent of Documents, Washington, D.C. - - - - - - - Price 5 cents